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<p>(54) Title: DEVELOPMENT CONTROL SYSTEM</p> <p>(57) Abstract</p> <p>Toning apparatus (23) for toning an electrostatic latent image, having image and background portions at different potentials on an imaging surface (16). The apparatus comprises an endless toning surface (21) coated with a layer of concentrated liquid toner and engaging the imaging surface (16) at a toning region. The apparatus additionally comprises a source of voltage connected to the toning surface (21) and electrifying the toning surface (21) to a voltage operative to selectively transfer at least a portion of the layer to image portions on the imaging surface (16). A developed mass per unit area (DMA) controller having an input indicative of the DMA on the imaging surface (16) is operative to adjust the DMA on the toning surface (21) in response to the input.</p>		

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- 1 -

DEVELOPMENT CONTROL SYSTEMFIELD OF THE INVENTION

The present invention relates to development control in electrostatographic imaging and, more particularly, to liquid toner development control.

BACKGROUND OF THE INVENTION

Generally, there are two types of development systems employed by electrostatographic imaging apparatus, namely, powder toner development systems and liquid toner development systems. Although powder toner is more conventional, liquid toner is often preferred for its higher intrinsic resolution. Considerable efforts have been made in the past to design more efficient and more convenient liquid toner development systems.

Liquid toner systems are sensitive to physical changes in the toner, such as changes in temperature, charge level, viscosity and liquid concentration, most of which are not relevant in powder toner systems. It is appreciated that these toner changes may affect the development level, thereby resulting in inconsistent imaging. Therefore, control of the liquid toner properties is generally considered to be crucial for maintaining a constant level of developed mass per unit area (DMA) on a photoreceptor of the imaging apparatus.

One current approach to maintaining image quality measures the optical density, volume and conductivity of the liquid toner used in the process. Based on these measurements, toner concentrate, carrier liquid or charge director, respectively are added to the liquid toner. Such an approach is described in U.S. Patent 4,860,932, the disclosure of which is incorporated herein by reference.

It is appreciated that construction and maintenance of

- 2 -

1 a closed loop development system as described above is both
2 complex and expensive. Therefore, liquid toner development
3 systems have never been embodied in low-cost disposable
4 cartridges, as normally is the case in powder toner
5 systems.

6 In U.S. Patent 4,341,461, the bias voltage of a
7 development roller in a powder development system is
8 adjusted in accordance with a measurement of toner density
9 on a developed patch on a photoreceptor. The toner density
10 is measured by an infrared densitometer which apparently
11 measures the optical density of the layer of toner
12 developed on the photoreceptor.

13 U.S. Patent 4,678,317 describes a liquid toner system
14 in which a sensor electrode is used to sense the potential
15 of a charged photoreceptor and to adjust a development
16 electrode voltage to compensate for variations in the
17 sensed potential.

18 WO 93/01531, the disclosure of which is incorporated
19 herein by reference, describes a direct-transfer liquid
20 toner development system. A layer of concentrated liquid
21 toner coating a toning roller is brought into virtual
22 contact with a photoreceptor, and portions of substantially
23 even thickness are transferred from the toning roller onto
24 attractive portions of the photoreceptor. Either the full
25 thickness of the portions is transferred, in a binary mode
26 of operation or, in a quasi-binary mode of operation, a
27 partial yet even thickness is transferred. The voltage
28 between the toning roller and the photoreceptor determines
29 the thickness of the layer which is transferred. In the
30 binary mode, the DMA on the photoreceptor is substantially
31 equal to the DMA on the toning roller and, in the quasi-
32 binary mode, the photoreceptor DMA is dependent in a well

- 3 -

1 defined manner upon the toning roller DMA. For quasi-binary
2 transfer the photoreceptor DMA is generally more uniform
3 than the toning roller DMA.

4 The direct-transfer system described above normally
5 employs a toner applicator and a squeegee associated with
6 the toning roller.

7 SUMMARY OF THE INVENTION

8 It is an object of the present invention to provide an
9 improved liquid toning system. In accordance with a
10 preferred embodiment of the present invention, consistent
11 toning of latent electrostatic images is maintained
12 throughout numerous toning cycles without adding liquid
13 toner or liquid toner components to the system and/or
14 adjusting the material composition of the liquid toner,
15 i.e. the ratio between toner particles and carrier liquid.

16 In general, liquid toner including charged toner
17 particles and carrier liquid is contained in a sump of the
18 toning system. The toner particles are selectively removed
19 from the liquid toner during the toning process as they are
20 transferred to a latent image bearing surface such as a
21 photoreceptor. The carrier liquid is generally removed at a
22 different rate, usually a lower rate. Thus, the percentage
23 of toner particles in the liquid toner, hereinafter
24 referred to as the solids concentration, rises or falls as
25 a function of the total area toned by the toning system.
26 For some colors, for which the proportion of printed
27 surface to unprinted surface is small, the solids
28 concentration may rise with time.

29 When either the solids concentration or the total
30 quantity of liquid toner in the system is reduced below a
31 pre-set value, either the sump or the entire toning system
32 is replaced or refilled.

- 4 -

1 In accordance with a preferred embodiment of the
2 present invention, there is thus provided a direct transfer
3 toning system including an endless toning surface,
4 preferably the surface of a toning roller charged to a
5 predetermined voltage, coated with a layer of toner
6 concentrate, a developed mass per unit area (DMA)
7 controller having an input for receiving an indication of
8 the DMA on an imaging surface such as a photoreceptor, and
9 adjusting the DMA on the toning surface in response to the
10 received input, whereby the DMA on the toning roller is
11 maintained substantially constant.

12 Preferably, the DMA controller controls at least one
13 voltage which affects the DMA on the toning roller.

14 According to one aspect of the present invention, the
15 input to the DMA controller is supplied by a DMA sensor
16 which monitors the DMA on the imaging surface. Since, in
17 direct-transfer toning systems, the DMA on the imaging
18 surface is dependent upon the DMA on the toning roller, by
19 controlling the DMA on the toning roller, a consistent
20 toning level is readily maintained.

21 In one embodiment of this aspect of the invention, the
22 DMA sensor includes an optical sensor which monitors the
23 optical density (OD) on the surface of the photoreceptor
24 or, alternatively, on the surface of the toning roller and
25 supplies an indication of the OD to the input. In this
26 case, the DMA controller includes a comparator which
27 compares the signal to a value representative of a desired
28 DMA and adjusts at least one voltage to produce the desired
29 DMA.

30 In accordance with another aspect of the present
31 invention, the input to the DMA controller is generated by
32 a solids concentration indicator responsive to the solids

- 5 -

1 concentration of the liquid toner. In this aspect of the
2 invention the development system preferably further
3 includes apparatus for measuring the temperature of the
4 toner. Based on the solids concentration indication and the
5 measured toner temperature, the at least one voltage is
6 adjusted according to a look-up table to provide the
7 desired DMA.

8 According to one, preferred, embodiment of this aspect
9 of the invention, the solids concentration indicator
10 includes a concentration detector which measures the
11 concentration of solids in the toner. The concentration
12 detector may include a viscosity sensor, an optical sensor,
13 a permittivity sensor or a sensor of any other property of
14 the toner which is related to the solids concentration.

15 According to another, preferred, embodiment of this
16 aspect of the invention, the solids concentration indicator
17 includes a concentration calculator which generates an
18 output responsive to the total area toned by the toning
19 system since the last refill/replacement of the toning
20 system. Since the total toned area can be approximated by
21 the number of toning cycles performed by the system, the
22 concentration calculator may include a counter of the
23 number of toning cycles performed since the last
24 refill/replacement of the system. It is appreciated that
25 the concentration of solids in the liquid toner is
26 substantially a function of the total area toned and, thus,
27 only approximately, a function of the number of toning
28 cycles performed by the system.

29 Alternatively or additionally, the proportion of
30 printed to non-printed area on each of the cycles is
31 calculated and the amount of carrier liquid and toner
32 particles per page is determined. In this embodiment the

- 6 -

1 concentration calculation would be improved over the
2 concentration calculation of the previous embodiment.

3 In a preferred embodiment of the invention, the
4 concentration calculator is at least partially comprised in
5 a "smart chip" which is part of the cartridge. In this
6 case, the smart chip stores specific concentration
7 information for the cartridge. This allows replacement of
8 cartridges without having to reset any counts on the
9 computer. For example, it is sometimes useful to print with
10 inks having special properties, such as fluorescent inks or
11 non-process color inks. Since these cartridges are used
12 only intermittently and must be removed when another
13 special color is to be printed, it is very useful to have
14 the concentration information attached to the cartridge
15 itself.

16 The accuracy of the calculation of toner particle
17 usage may be improved by using the DMA measurement to
18 determine more accurately the amount of toner particles per
19 unit printed area. A level detector in the sump may be used
20 to determine the amount of liquid toner which has been
21 removed from the sump. This determination, together with
22 the determination of the amount of toner particles used in
23 printing, can be used to give a very accurate determination
24 of the concentration.

25 For improved development control, the liquid toner in
26 the development system preferably includes a toner charge
27 stabilizer operative for maintaining a substantially con-
28 stant level of electric charge per unit mass (hereinafter
29 Q/M) in the liquid toner. In a preferred embodiment, the
30 toner charge stabilizer includes a charge director.

31 Further, in accordance with a preferred embodiment of
32 the invention, the development system includes an

- 7 -

1 applicator manifold for supplying liquid toner and coating
2 the toning surface with a layer of concentrated liquid
3 toner. A portion of the applicator manifold juxtaposed
4 with the toning surface, hereinafter referred to as the
5 coating electrode, is preferably charged to a relatively
6 high voltage which aids the coating process. Preferably,
7 the DMA controller includes apparatus for adjusting the
8 voltage on the applicator manifold.

9 Preferably, the toning system includes a squeegee
10 roller associated with the toning surface and electrified
11 to a voltage different from that of the toning surface.
12 Preferably, the DMA controller controls the squeegee
13 voltage on the squeegee roller in response to the input
14 received from the DMA monitor or the concentration
15 indicator and the temperature sensor, in accordance with
16 the alternative aspects of the present invention described
17 above.

18 For the preferred embodiment described herein, the DMA
19 on the toning surface is a function, inter alia of the
20 voltages on the applicator manifold and the squeegee
21 roller.

22 In a preferred embodiment of the invention, the
23 squeegee roller is urged against the surface of the toning
24 roller by the action of a leaf spring. The portion of the
25 leaf spring in contact with the squeegee roller is
26 preferably coated with a compressible pad which is, more
27 preferably, formed of a closed cell foam or elastomer.

28 In a preferred embodiment of the present invention,
29 the toning system is embodied in a replaceable cartridge.

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32

- 8 -

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 The present invention will be understood and
3 appreciated more fully from the following detailed
4 description, taken in conjunction with the drawings in
5 which:

6 Fig. 1 is a schematic diagram of imaging apparatus
7 constructed and operative in accordance with a preferred
8 embodiment of the present invention;

9 Figs. 2A and 2B are schematic diagrams of multi-color
10 imaging apparatus in accordance with preferred embodiments
11 of the present invention;

12 Figs. 3A and 3B are schematic, cross-sectioned
13 illustrations of a toning assembly in accordance with a
14 preferred embodiment of the invention;

15 Fig. 4A is a schematic, cross-sectional view of the
16 toning assembly of Figs. 3A and 3B along line IV A;

17 Fig. 4B is a schematic, cross-sectional view of the
18 toning assembly of Figs. 3A and 3B along line IV B;

19 Fig. 5A is a simplified block diagram of toning
20 control apparatus, in accordance with one aspect of the
21 present invention;

22 Fig. 5B is a simplified block diagram of toning
23 control apparatus, in accordance with another aspect of the
24 present invention;

25 Fig. 6 is a more detailed schematic illustration of a
26 portion of the assembly of Figs. 3A - 4B, in accordance
27 with a preferred embodiment of the present invention;

28 Figs. 7 and 8 are graphs showing the dependence of
29 liquid toner viscosity and toner charge density,
30 respectively, on toner temperature; and

31 Figs. 9 is an experiment-based graph showing the
32 dependence of DMA on toner concentration.

- 9 -

1 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

2 Reference is now made to Fig. 1 which illustrates
3 imaging apparatus constructed and operative in accordance
4 with a preferred embodiment of the present invention.

5 The apparatus of Fig. 1 includes a drum 10 arranged
6 for rotation in a direction generally indicated by arrow
7 14. Drum 10 is covered by an imaging surface 16 such as a
8 cylindrical photoconductive surface made of selenium, a
9 selenium compound, an organic photoconductor or any other
10 suitable photoconductor known in the art.

11 In operation, drum 10 rotates and surface 16 is
12 charged by a charger 18 to a generally uniform,
13 predetermined, voltage typically on the order of -900 to
14 -1000 volts. Charger 18 may be any type of charger known
15 in the art, such as a corotron, scorotron or charging
16 roller.

17 Continued rotation of drum 10 brings charged surface
18 16 into image receiving relationship with an exposure means
19 such as a light source 19, which may be a laser or LED
20 scanner (in the case of a printer) or the projection of an
21 original (in the case of a photocopier). Light source 19
22 forms a desired electrostatic latent image on charged
23 photoconductive surface 16 by selectively discharging
24 portions of the photoconductive surface, image portions
25 being at a first voltage and background portions at a
26 second voltage. The discharged portions preferably have a
27 voltage of between zero and about (-200) volts.

28 Other methods of providing an electrostatic latent
29 image on the imaging surface (and other types of imaging
30 surfaces) are also useful in the practice of the invention.
31 For example the imaging surface may be an electrostatic
32 master in which case the light source is omitted, or an

- 10 -

1 ionographic or other system as is known in the art may be
2 substituted for the photoreceptor, charger and light
3 source.

4 Continued rotation of drum 10 brings charged
5 photoconductive surface 16, bearing the electrostatic
6 latent image, into operative engagement with the surface 21
7 of a toning roller 22 which is part of a toning assembly
8 23, more fully described below with reference to Figs. 3A,
9 3B, 4A and 4B. In a preferred embodiment of the present
10 invention, assembly 23 is contained in a disposable
11 cartridge which may be replaced after a preselected number
12 of imaging cycles or after the liquid toner contained
13 therein is effectively depleted.

14 Toning roller 22 rotates in a direction opposite that
15 of drum 10, as shown by arrow 13, such that there is
16 substantially zero relative motion between their respective
17 surfaces at the point of contact. Surface 21 of toning
18 roller 22 is preferably composed of a soft polyurethane
19 material, preferably made more electrically conductive by
20 the inclusion of conductive additives, while the bulk of
21 toning roller 22 may be composed of any suitable
22 electrically conductive material and preferably includes a
23 metal core. Alternatively, drum 10 may be formed of a
24 relatively resilient material, and in such a case surface
25 21 may be composed of either a rigid or compliant material.

26 As described below, surface 21 is coated with a thin
27 layer of liquid toner, preferably having a high
28 concentration of charged toner particles. In the present
29 example the charges are assumed to be charged negatively.
30 Developer roller 22 is charged to a voltage which is
31 intermediate the voltage of the charged and discharged
32 areas on photoconductive surface 16, preferably in the

- 11 -

1 order of -500 to -600 volts.

2 When surface 21 bearing the layer of liquid toner is
3 engaged with photoconductive surface 16 of drum 10, the
4 difference in potential between toning roller 22 and
5 surface 16 causes selective transfer of the layer of
6 concentrated liquid toner to surface 16, thereby toning the
7 latent image. Depending on the choice of toner charge
8 polarity and the use of a "write-white" or "write-black"
9 system, the layer will be selectively attracted to either
10 the charged or discharged areas of surface 16, and the
11 remaining portions of the toner layer will continue to
12 adhere to surface 21. In a preferred embodiment of the
13 invention, the concentration of toner on surface 16 is
14 between 20 and 40 percent solids, more preferably between
15 25 and 30 percent solids.

16 For multicolor systems, as shown in Fig. 2A, a
17 plurality of toning rollers, one for each color, are
18 provided. The toning rollers are sequentially engaged with
19 surface 16 to develop sequentially produced latent images.
20 The plurality of toning rollers 22 are part of a respective
21 plurality of toning assemblies 23, wherein each assembly
22 includes liquid toner of a different color.

23 Alternatively, as shown in Fig. 2B, the plurality of
24 toning assemblies 23 may be positioned side by side as for
25 example on a chassis (not shown). The toning assembly
26 containing the desired color for printing is brought into
27 alignment by moving the chassis sideways as indicated in
28 the drawing. The toning assembly to be used is then urged
29 against drum 16 by a spring or other means (not shown).

30 In one preferred mode of operation, hereinafter
31 referred to as the binary mode, attracted portions of the
32 toner layer are completely transferred to the photoreceptor

- 12 -

1 surface. Alternatively, in another preferred mode of
2 operation, hereinafter referred to as the quasi-binary
3 mode, the selective transfer of toner from surface 21 to
4 surface 16 is only partial. The quasi-binary mode is
5 achieved when the voltage difference between the image
6 portions and the voltage of surface 21 is relatively low
7 and/or the developed mass per unit area (DMA) on surface 21
8 is relatively large (typically 0.2 milligram per square
9 centimeter). However even in the quasi-binary mode, the
10 resultant DMA on surface 16 is strongly dependent upon the
11 DMA on surface 21 of toning roller 22.

12 For the quasi-binary system, the difference in poten-
13 tial (i.e. the voltage) between the image areas on surface
14 16 and surface 21 is chosen so that only the desired amount
15 of charged toner particles are transferred to charged
16 portions of surface 16. In this system the voltage and the
17 total charge on the particles in the toner layer are chosen
18 such that the direction of the electric field reverses
19 itself within the layer. That portion of the layer which is
20 between the reversal plane and surface 16 will be attracted
21 to surface 16 and the rest of the layer will be attracted
22 to surface 21. If the viscosity and cohesiveness of the
23 layer are not too high, the layer will split along the
24 reversal plane. Providing the charge per unit mass is kept
25 constant, the DMA which is transferred to surface 16 will
26 be more uniform than that on surface 21. However, the DMA
27 on imaging surface 16 is dependent on the thickness and DMA
28 of the layer on surface 21.

29 The latent image toned by means of the processes
30 described above may then be directly transferred to a
31 desired substrate in a manner well known in the art.
32 Alternatively, as shown in Fig. 1, there may be provided an

- 13 -

1 intermediate transfer member 40, which may be a drum or
2 belt and which is in operative engagement with
3 photoconductive surface 16 of drum 10 bearing the developed
4 image. Intermediate transfer member 40 rotates in a
5 direction opposite to that of photoconductive surface 16,
6 as shown by arrow 43, providing substantially zero relative
7 motion between their respective surfaces at the point of
8 image transfer.

9 Intermediate transfer member 40 receives the toner
10 image from photoconductive surface 16 and transfers it to
11 a final substrate 42, such as paper. A heater 45 may be
12 disposed internally of intermediate transfer member 40 to
13 heat intermediate transfer member 40, as is known in the
14 art. Transfer of the image to intermediate transfer member
15 40 is preferably aided by providing electrification of
16 intermediate transfer member 40 to provide an electric
17 field between intermediate transfer member 40 and the image
18 areas of imaging surface 16. Intermediate transfer member
19 40 preferably has a conducting layer 44 underlying an
20 elastomer layer 46, which is preferably a slightly
21 conductive resilient polymeric layer.

22 Various types of intermediate transfer members are
23 known and are described, for example in U.S. Patent
24 4,684,238, PCT Publication WO 90/04216 and U.S. Patent
25 4,974,027, the disclosures of all of which are incorporated
26 herein by reference.

27 In a preferred embodiment of the invention the various
28 layers of intermediate transfer member 40 are formed by the
29 following method:

30 FORMULATION

31 Blend A is prepared by diluting 100 grams of adhesive
32 (preferably Chemlok 218 distributed by Lord Chemical) with

- 14 -

1 100 grams of MEK solvent. 5.2 grams of conductive carbon
2 black (preferably Printex XE2, distributed by Degussa). The
3 mixture is charged into an 01 attritor (Union Process) and
4 ground for 5 hours at 10°C.

5 Blend B is prepared by mixing 30 grams of SylOff 7600
6 (Dow Corning) with 3 grams of SylOff 7601 (Dow Corning) and
7 450 grams of n-Hexane and shaking the mixture well.

8 Blend C is prepared by blending 90 grams of
9 Polyurethane resin (Monotane A20) with 90 grams of Monotane
10 A30 (C.I.L., England) and heating and stirring the blend
11 under vacuum at 80°C for 16 hours and at 120°C for an
12 additional hour.

13 MANUFACTURING PROCESS

14 A metal core for the intermediate transfer member is
15 coated with the required layers by the following process:

16 The metal core is painted with a thin layer of Blend A
17 and dried for one hour at 110°C.

18 The inner side of a mold having a diameter
19 approximately 4 millimeters larger than the core is dip
20 coated with Blend B. The coated mold is cured for one hour
21 at 110°C.

22 The coated mold and the coated core are preheated to
23 80°C before casting. The hot mold is filled with hot
24 (120°C) Blend C. The core is carefully inserted into the
25 mold and the system is cured for 8 hours at 135°C. Removal
26 of the cured intermediate transfer member is aided by
27 dripping Isopar L (Exxon) on the inner side (edge) of the
28 mold.

29 A 3 micrometer thick release layer is added to the
30 intermediate transfer member by dip coating the member in
31 RTV 236 dispersion (Dow Corning) and curing the layer.

32 The resulting layer has a thickness of approximately 2

- 15 -

1 millimeters and the resistivity of the Blend C material at 2 50°C is about 10^9 ohm-cm.

3 Following the transfer of the toner image to substrate
4 42 or to intermediate transfer member 40, photoconductive
5 surface 16 engages a cleaning station 49, which may be any
6 conventional cleaning station. A scraper 56 completes the
7 removal of any residual toner which may not have been
8 removed by cleaning station 49. A lamp 58 then completes
9 the cycle by removing any residual charge, characteristic
10 of the previous image, from photoconductive surface 16.

11 In a preferred embodiment of the invention a pre-
12 transfer discharge lamp (not shown) is used to reduce
13 charge on the portion of the photoreceptor behind the toner
14 (i.e., on the image portions), it being noted that the
15 background portions are discharged during the formation of
16 the latent image. This reduces the amount of arcing which
17 occurs during transfer of the image to the intermediate
18 transfer member. A preferred embodiment of a pre-transfer
19 discharge lamp is disclosed in U.S. Patent 5,166,734, the
20 disclosure of which is incorporated herein by reference.

21 The present inventors have found that, if such a pre-
22 transfer lamp is used and a roller charger is used for
23 charger 18, then lamp 58 may be omitted.

24 Reference is now made to Figs. 3A and 4A, which
25 illustrate in more detail developer assembly 23 in
26 accordance with a preferred embodiment of the present
27 invention. In addition to toning roller 22, which has been
28 described above, toning assembly 23 preferably includes a
29 squeegee roller 78, a cleaning roller 84, an applicator 64
30 and an agitator 66, all contained within a preferably
31 replaceable housing 75. The lower part 77 of housing 75,
32 hereinafter referred to as a sump 77, is at least partially

- 16 -

1 filled with liquid toner. All of the above mentioned
2 elements contained in 75 are described below in greater
3 detail.

4 In operation, agitator 66 rotates in a preselected
5 direction constantly agitating the toner in sump 77,
6 thereby ensuring the homogeneity of the toner throughout
7 the toning process. Agitator 66 is preferably powered
8 through an input shaft 68, as seen particularly in Fig. 3A.
9 Input shaft 68 is preferably also associated with toner
10 pumping apparatus which will be described in detail below.

11 Reference is now also made to Figs. 3B and 4B which
12 illustrate additional portions of developer assembly 23 not
13 seen in Figs. 3A and 4A. Assembly 23 preferably includes a
14 gear pump 100 having a pair of interlaced cogged gears 102
15 which rotate in opposite directions, as indicated generally
16 by arrows 103. This rotation of gears 102 provides upward
17 pumping action which pumps toner from an intake pipe 104,
18 associated with sump 77, to an output pipe 106 associated
19 with a toner application manifold 108 having a lower level
20 107 and an upper level 109. In a preferred embodiment of
21 the invention, application manifold 108 is formed within
22 applicator 64, which is preferably made of a rigid, non-
23 conductive, preferably plastic, material. The upper surface
24 112 of applicator 64, i.e. the surface juxtaposed with
25 surface 21 of toning roller 22, is preferably coated with a
26 conductive layer. The conductive layer is preferably
27 charged to a high voltage, preferably in the order of -1100
28 to -1200 volts. Surface 112 is hereinafter referred to as
29 applicator electrode 112.

30 During operation of assembly 23, toner is pumped by
31 pump 100 out of sump 77 and into application manifold 108.
32 As seen in Fig. 3B pipe 106 connects pump 100 to lower

- 17 -

1 level 107 of manifold 108, while Fig. 4A shows a toner
2 passage 111 between lower level 107 and upper level 109. By
3 virtue of the pressure produced at pump 100, the toner in
4 upper level manifold 109 is released via a plurality of
5 application tunnels 114, through applicator electrode 112
6 of applicator 64, into an application region 116 formed in
7 the narrow space between roller 22 and electrode 112.

8 The voltage difference between electrode 112 and
9 toning roller 22 causes repulsion of the charged toner
10 particles in application region 116 from electrode 112 and
11 attraction of the particles to toning roller 22, thereby
12 coating toning roller 22 with a layer of concentrated
13 liquid toner.

14 As shown in Figs. 4A and 4B, squeegee roller 78 is
15 situated near surface 21 of toning roller 22 and is
16 preferably urged by a leaf spring 80 against surface 21.
17 Squeegee roller 78 is preferably constructed of a rigid
18 conductive material, optionally coated with a thin layer of
19 polymer material, and is preferably biased by a voltage in
20 the order of -1000V, such that the outer surface of
21 squeegee 78 repels the charged particles of the toner layer
22 on surface 21. The mechanical pressure and the electric
23 repulsion of roller 78 are operative to squeegee the layer
24 of toner, so that the layer of toner will be more
25 condensed and uniform as surface 21 of roller 22 comes
26 into contact with image carrying surface 16.

27 Since coating region 116 preferably extends to the
28 vicinity of squeegee roller 78, as can be seen in Fig. 4A,
29 additional toner particles may be coated onto surface 22,
30 in accordance with the voltage on squeegee roller 78. Thus,
31 squeegee roller may also act as a coating electrode. By
32 adjusting the pressure applied by leaf spring 80 and by

- 18 -

1 biasing the roller to an appropriate voltage, the thickness
2 and density of the toner layer can be adjusted to a
3 desirable level.

4 Squeegee roller 78 preferably rotates in a direction
5 opposite that of toning roller 22, such that there is
6 substantially zero relative motion between their respective
7 surfaces at the region of contact. In one embodiment of the
8 invention, the common surface speed of rollers 22 and 78
9 is approximately 2 inches per second, which preferably
10 matches the speed of imaging surface 16.

11 The excess fluid which is removed by squeegee roller
12 78 is returned by gravity to sump 77 for reuse.

13 The solids content of the layer is mainly a function
14 of the mechanical properties of the rollers and of the
15 voltages applied and pressures and is only slightly
16 influenced by the initial toner concentration for a
17 considerable range of initial toner concentrations.

18 Reference is now made to Fig. 6, which illustrates in
19 more detail squeegee roller 78 urged by leaf spring 80.
20 Leaf spring 80 preferably includes a relatively rigid metal
21 spring body 90 and a relatively soft, preferably
22 compressible, pad 92. Pad 92 is attached to spring body 90
23 at the portion of leaf spring 80 which urges roller 78,
24 such that direct contact between spring body 90 and roller
25 78 is avoided. It should be appreciated that pad 92 pro-
26 tects squeegee 78 from being scratched or otherwise damaged
27 and, thus, extends the useful lifetime of squeegee 78. Pad
28 92 is preferably formed of a resilient material, preferably
29 a closed-cell foam or elastomer, such as Hydrine, Neoprene
30 or Nitrile. A preferred material is a soft closed cell and
31 hydrocarbon resistant material such as Epichlorohydrin
32 elastomer available from Regumi, Petach Tikva, Israel.

- 19 -

1 It is a feature of a preferred embodiment of the
2 present invention that scratching of squeegee roller 78 is
3 prevented by virtue of pad 92. It should be noted that
4 other techniques and/or apparatus tested in the past have
5 failed to prevent such wear of the squeegee. Even Teflon
6 coating of the leaf spring has failed to provide adequate
7 protection.

8 As described above, the layer of liquid toner which is
9 deposited on surface 21 of roller 22 is selectively
10 transferred to photoconductive surface 16 in the process of
11 toning the latent image. In principle, the portions of the
12 toner layer that have not been used in the development of
13 the latent image need not be removed from toning roller 22.
14 However, a cleaning station 84, comprising a sponge or a
15 brush or similar apparatus, is preferably provided to
16 remove the remaining toner concentrate from surface 21 of
17 toning roller 22, especially if the toner is of a type
18 which is discharged by the electric fields in the interface
19 between the surfaces of toning roller 22 and surface 16.
20 The toner so removed returns by gravity to sump for reuse
21 after being remixed with the remaining liquid toner by
22 agitator 66.

23 Cleaning station 82 (shown in Figs. 4A and 4B)
24 preferably comprises a sponge roller 84, which is
25 preferably formed of a resilient open cell material, such
26 as foamed polyurethane. Roller 84 is situated such that it
27 resiliently engages a portion of surface 21 between the
28 transfer area (i.e. the area of surface 21 engaged by
29 surface 16) and the application area, thereby removing
30 residual toner from surface 21 before the application of
31 new toner. In a preferred embodiment of the invention,
32 sponge roller 84 rotates in the same direction as toning

- 20 -

1 roller 22, as indicated generally by arrow 85, but at a
2 surface velocity approximately 10 times higher than that of
3 roller 22. For example, if surface 21 of toning roller 22
4 moves at a speed of 2 inches per second, the surface of
5 roller 84 moves at approximately 20 inches per second. The
6 relative motion between the two surface assists in scraping
7 toner off surface 21.

8 It should be appreciated that the different parts of
9 toning assembly 23, as described in detail above, may be
10 constructed of inexpensive materials and contained in a
11 plastic housing 75, such that the entire toning assembly
12 can be replaced when the liquid toner is at the end of its
13 useful lifetime. Thus, it is a feature of the present
14 invention that the toning assembly may be disposable, in
15 contrast to prior art liquid toner systems which are not
16 generally suitable for being disposable apparatus.

17 Reference is now made to Figs. 5A and 5B which are
18 simplified block diagrams of two preferred embodiments of
19 toner control apparatus in accordance with the present
20 invention. Fig. 5A shows apparatus for controlling the DMA
21 on the toning roller, based on measurement of the DMA on
22 the toning roller or on the imaging surface. Fig. 5B shows
23 apparatus for controlling the DMA based on measurements of
24 physical properties of the toner which have been found to
25 affect the DMA and/or calculation of toner properties based
26 on usage of the cartridge.

27 In both embodiments, the toning control apparatus
28 preferably includes a voltage control unit 120 operative
29 for adjusting the voltage of one or both of application
30 electrode 112 or squeegee roller 78. In the apparatus of
31 Fig. 5A, the voltages are adjusted in accordance with
32 signals received from a DMA monitor 122. DMA monitor 122

- 21 -

1 receives an input from a DMA sensor, which is preferably an
2 optical sensor 124 such as an infrared densitometer which
3 views surface 21 of toning roller 22, imaging surface 16 or
4 intermediate transfer member 40. Optical sensor 124 is
5 operative for generating an output, responsive to the
6 optical density (OD) of the respective surface which is
7 received by DMA monitor 122.

8 In a preferred embodiment of the invention, the DMA is
9 optically measured on the intermediate transfer member.
10 This measurement has been found to be more accurate than
11 measuring the DMA in other places.

12 DMA monitor 122 preferably compares the output of
13 optical sensor 124 to a pre-determined value which is
14 indicative of the desired DMA required. While the optical
15 density may be measured on either roller 21 or surface 16,
16 either measurement may be related to a desired DMA and
17 optical density on the imaging surface. If the optical
18 density is measured on the imaging surface, a patch is
19 generally toned on the imaging surface to act as a
20 reference.

21 In the apparatus of Fig. 5B, the voltages of squeegee
22 roller 78 and electrode 112 are adjusted based on command
23 signals received from a DMA calculator 126. In one
24 preferred embodiment of the present invention, the DMA
25 calculator includes a developer usage indicator 127
26 operative for providing calculator 126 with an indication
27 responsive to the total area developed by development
28 assembly 23, or to the number of copies/prints developed.
29 The DMA calculator then determines, preferably by reference
30 to an electronic "look-up table", the appropriate voltages
31 of surface 112 and roller 78 to give the desired DMA.

32 Alternatively, the proportion of printed to non-

- 22 -

1 printed area on each of the cycles is calculated and the
2 amount of carrier liquid and toner particles per page is
3 determined. In this embodiment the concentration
4 calculation would be improved over that of the previous
5 embodiment.

6 In a preferred embodiment of the invention, the usage
7 indicator and/or DMA calculator are at least partially
8 comprised in a "smart chip" which is part of the cartridge.
9 In this case the smart chip stores specific concentration
10 information for the cartridge. This allows replacement of
11 cartridges without having to reset any counts on the
12 computer. For example, it is sometime useful to print with
13 inks having special properties, such as fluorescent inks or
14 non-process color inks. Since these cartridges are used
15 only intermittently and must be removed when another
16 special color is to be printed, it is very useful to have
17 the concentration information attached to the cartridge.
18 itself.

19 The accuracy of the calculation of toner particle
20 usage may be improved by using the DMA measurement to more
21 accurately determine the amount of toner particles per unit
22 printed area. A level detector in the sump may be used to
23 determine the amount of liquid toner which has been removed
24 from the sump. This determination, together with the
25 determination of the amount of toner particles used in
26 printing can be used to give a very accurate determination
27 of the concentration.

28 The DMA is a function of the charge per unit mass of
29 the toner, the solids concentration and the temperature.
30 Therefore, in an alternative embodiment of the invention,
31 the developer usage indicator is replaced by a toner
32 concentration sensor 128 which provides an electric output

- 23 -

1 responsive to the solids concentration in the liquid toner.
2 Toner concentration sensor 128 may include a toner
3 viscosity sensor 129 which may be a differential pressure
4 sensor. Alternatively, the concentration sensor may include
5 an optical sensor for measuring the optical density of the
6 toner in the sump, an ultrasonic sensor or a permittivity
7 sensor for measuring properties of the toner concentrate
8 which are related to the solids concentration in the sump.

9 The toner temperature affects both the viscosity and
10 charge density (Q/M) of the toner and, thus, the DMA.
11 Therefore, in a preferred embodiment of the invention, the
12 development control system includes a toner temperature
13 sensor 130, preferably located in the toner sump.
14 Temperature sensor 130 provides DMA calculator 126, in the
15 embodiment of Fig. 5B, with an electric input responsive to
16 the temperature of the liquid toner. The temperature input
17 is used by calculator 126, using stored DMA vs. temperature
18 data, in determining the control signals generated to
19 voltage control unit 120.

20 Figs. 7 and 8 illustrate the temperature dependence of
21 the toner viscosity (in centipoise) and toner charge densi-
22 ty (in microcoulomb per gram), respectively for the
23 preferred toner. The curve marked "Marcol-82" in Fig. 7 is
24 the temperature vs. viscosity curve for the carrier liquid
25 used in the preferred toner. By using look-up tables based
26 on experimental graphs such as Figs. 7 and 8, DMA monitor
27 122 (or calculator 126) performs the required temperature
28 compensation.

29 Fig. 9 is a graph of experimental data showing the
30 relationship between the DMA (on toning roller 22) and the
31 solids concentration in the toner for the preferred toner
32 for various squeegee 78 to roller 22 voltage differences.

- 24 -

1 As can be seen in Fig. 9, the DMA on roller 22 remains
2 fairly stable over a wide range of toner concentrations
3 but drops rapidly under a predetermined level of toner
4 concentration. Thus, by including experiment-based look-up
5 tables in the circuitry of DMA calculator 126, toner
6 concentration data can be properly interpreted to
7 corresponding DMA data.

8 Additionally, the charged and discharged voltage on
9 the photoreceptor may be measure or calculated (based on
10 usage of the photoreceptor) using methods which are well
11 known in the art. The charging voltage may then be adjusted
12 as may be the voltage of roller 22. This generally requires
13 the adjustment of the applicator and squeegee voltages as
14 well. It is also possible to use the applicator and
15 squeegee voltage to compensate for aging effects in the
16 photoreceptor.

17 It is a feature of a preferred embodiment of the
18 present invention that liquid toner can be used over a wide
19 range of concentrations. By proper compensation of the
20 voltages of squeegee roller 78 and electrode 112, the DMA
21 on toning roller 22 (and hence of imaging surface 16) can
22 be maintained substantially constant. This can be
23 appreciated from Fig. 9, where it is seen that differences
24 in the voltage between squeegee roller 78 and toning roller
25 22 result in corresponding difference in the DMA on roller
26 22.

27 A preferred toner for use in the invention is prepared
28 as follows:

29 COMPOUNDING

30 865.4 grams of Surlyn 1605 ionomer (DuPont), 288.5
31 grams of Mogul-L (Cabot), 28.8 grams of copper Phtalocynin
32 (Cookson Pigments) and 17.3 grams of Aluminum tristearate

- 25 -

1 (Merck) are compounded on an Idon two roll mill at 150°C
2 for 40 minutes.

3 SOLUBILIZATION

4 1000 grams of the result of the compounding step and
5 1500 grams of Marcol 82 mineral oil (EXXON) are charged
6 into a Ross double planetary mixer (two gallon size), pre-
7 heated to 200°C (hot oil heating). The material is heated
8 without mixing for one hour. Mixing is then started on low
9 speed (speed control setting 2) for 50 minutes, then raised
10 to a higher speed (SCS 4) for an additional 50 minutes. By
11 this time the material is completely solubilized and
12 homogeneous. The material is discharged from the mixer
13 while still warm. After cooling the material is passed
14 through a cooled meat grinder three times.

15 SIZE REDUCTION

16 862.5 grams of ground material from the previous step
17 (at 40% non-volatile solids concentration) and 1437.5 grams
18 of Marcol 82 are loaded into a 1S attritor (Union Process)
19 equipped with 3/16" carbon steel balls. The mixture is
20 ground at 250 RPM for 30 hours at 55°C. The material is
21 manually recycled through the system three times. The
22 material is then diluted to the required concentration
23 (normally 8-12% non-volatile solids) with Marcol 82 and
24 screened through a 300 micrometer screen. The material is
25 magnetically treated to remove metal contamination as is
26 known in the art.

27 CHARGING

28 The resulting concentrated toner is charged with the
29 following combination of materials.

30 1-Lubrizol 890 (Lubrizol Corporation) is added at a
31 level of 80 milligrams per gram solids and 1 milligram per
32 gram of Marcol 82; and

- 26 -

1 2-Petronate L (Witco) is added at a level of 20
2 milligrams per gram solid. The system is left to
3 equilibrate overnight before use.

4 Other color liquid toners are produced by a similar
5 process.

6 It will be appreciated by persons skilled in the art
7 that the present invention is not limited to what has been
8 particularly shown and described hereinabove. Rather, the
9 scope of the present invention is defined only by the
10 following claims:

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C L A I M S

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2 1. Toning apparatus for toning an electrostatic latent
3 image, having image and background portions at different
4 potentials, on an imaging surface comprising:
5 an endless toning surface, coated with a layer of
6 concentrated liquid toner and engaging the imaging surface
7 at a toning region;
8 a source of voltage connected to the toning surface
9 and electrifying the toning surface to a voltage operative
10 to selectively transfer at least a portion of the layer to
11 image portions on the imaging surface; and
12 a developed mass per unit area (DMA) controller having
13 an input indicative of the DMA on the imaging surface and
14 operative to adjust the DMA on the toning surface in
15 response to the input.
16
- 17 2. Apparatus according to claim 1 further comprising:
18 a source of liquid toner; and
19 an applicator which receives liquid toner from the
20 source and coats a concentrated layer of said liquid toner
21 onto the toning surface.
22
- 23 3. Apparatus according to claim 2 wherein the applicator
24 includes an applicator electrode charged to an applicator
25 voltage which affects the DMA of the coating, said
26 applicator voltage being controlled by the controller,
27 whereby the controller is operative to control the DMA on
28 the imaging surface.
29
- 30 4. Apparatus according to claim 2 or claim 3 and also
31 comprising:
32 a squeegee roller associated with the toning surface

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1 and charged to a squeegee voltage different from that of
2 the toning surface, said squeegee voltage being controlled
3 by the controller, whereby the controller is operative to
4 control the DMA on the imaging surface.

5

6 5. Apparatus according to claim 4 and further comprising
7 a leaf spring fixedly mounted on a first end portion
8 thereof and having a resilient pad mounted on a second end
9 portion thereof, said resilient pad being urged against
10 said squeegee roller by said leaf spring thereby urging the
11 squeegee roller against said endless surface.

12

13 6. Apparatus according to any of the preceding claims and
14 further comprising a DMA sensor which provides to the
15 controller input a signal responsive to the DMA of the
16 coating on the toning surface.

17

18 7. Apparatus according to any of claims 1-5 and further
19 comprising a DMA sensor which provides a signal to the
20 controller input responsive to the DMA of an image area on
21 the imaging surface.

22

23 8. Apparatus according to claim 6 wherein the DMA sensor
24 comprises an optical sensor associated with the toning
25 surface for measuring the optical density on a preselected
26 portion of the toning surface.

27

28 9. Apparatus according to any of claims 2-5 and further
29 comprising a solids concentration sensor which provides a
30 signal to the controller input responsive to the solids
31 concentration of the liquid toner in the source.

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1 10. Apparatus according to any of claims 2-5 or 9 and
2 further comprising a temperature sensor operative for
3 providing an output signal to the controller input
4 responsive to the temperature of the toner in the sump.
5

6 11. Apparatus according to claim 9 or 10 wherein the
7 solids concentration sensor comprises a viscosity sensor.
8

9 12. Imaging apparatus comprising:
10 an imaging surface having a latent electrostatic
11 image thereon; and
12 toning apparatus according to any of the preceding
13 claims operative for toning the image portions of the
14 latent image with a layer of liquid toner.
15

16 13. Imaging apparatus according to claim 12 wherein the
17 imaging surface is a photoconductive surface and further
18 comprising:

19 a charging station operative for charging the
20 photoconductive surface to a first voltage; and
21 an exposure station operative for selectively
22 discharging portions of the charged photoconductive,
23 thereby creating a latent image comprising image portions
24 at a second voltage and background portions at a second
25 voltage.

26

27 14. A replaceable toning cartridge comprising:

28 a housing adapted for mounting on a toner station of
29 an imaging apparatus in operative association with an
30 imaging surface thereof; and

31 toning apparatus according to any of claims 1-13
32 contained in said housing.

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2 15. Squeegeeing apparatus for use in electrostatic imaging
3 to squeegee an endless moving surface, comprising:
4 a squeegee roller associated with said endless moving
5 surface; and

6 a leaf spring fixedly mounted on a first end portion
7 thereof and having a resilient pad mounted on a second end
8 portion thereof, said resilient pad being urged against
9 said squeegee roller by said leaf spring thereby urging the
10 squeegee roller against said endless surface.

11
12 16. Imaging apparatus comprising:
13 an imaging surface having a latent electrostatic
14 image thereon;

15 toning apparatus according to claim 6 or claim 7
16 operative for toning the image portions of the latent image
17 with a layer of liquid toner; and

18 an intermediate transfer member which receives the
19 toned image from the imaging surface and transfers it to an
20 intermediate transfer member,

21 wherein the DMA sensor comprises an optical sensor
22 associated with the toning surface for measuring the
23 optical density on a preselected portion of the toning
24 surface.

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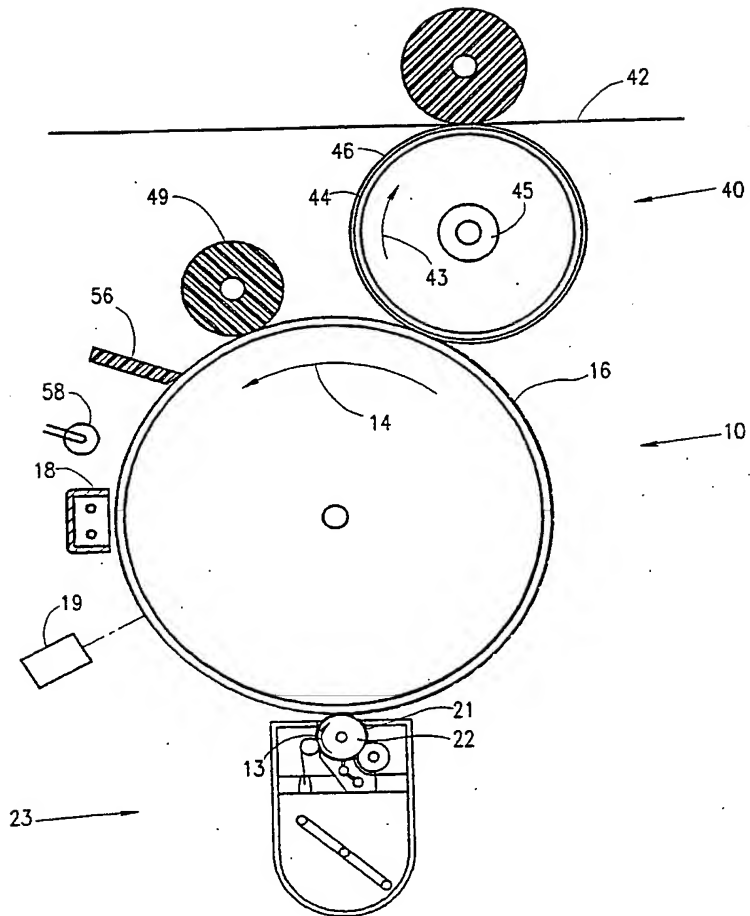


FIG.1

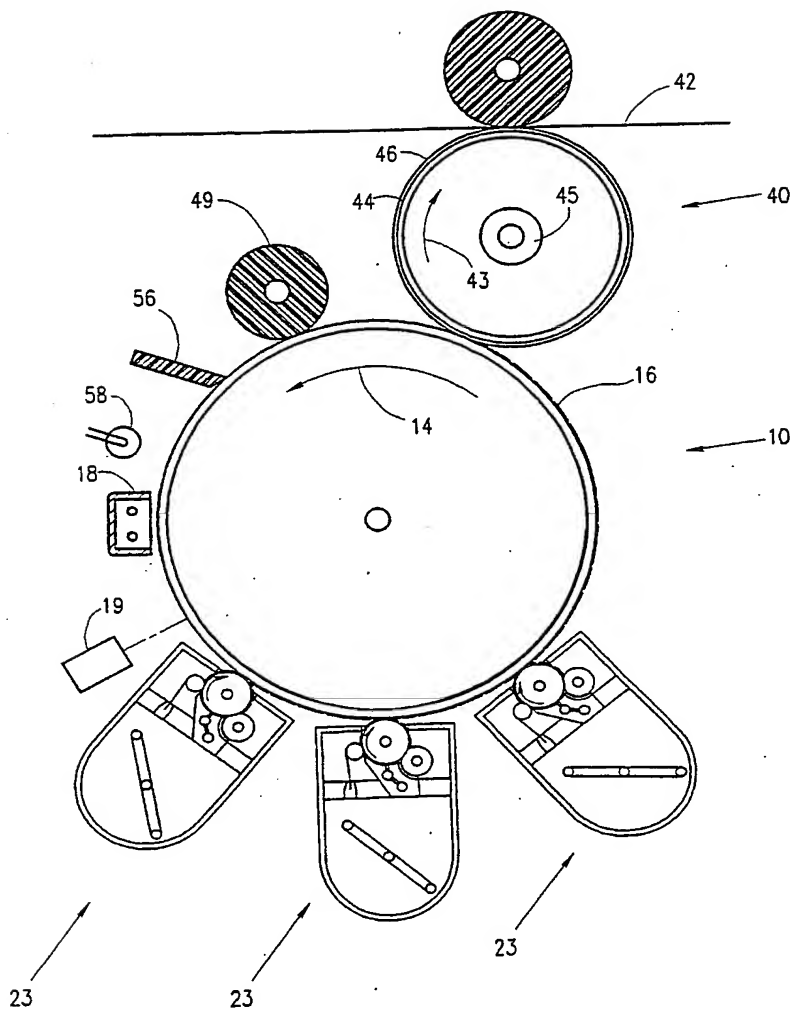


FIG. 2A

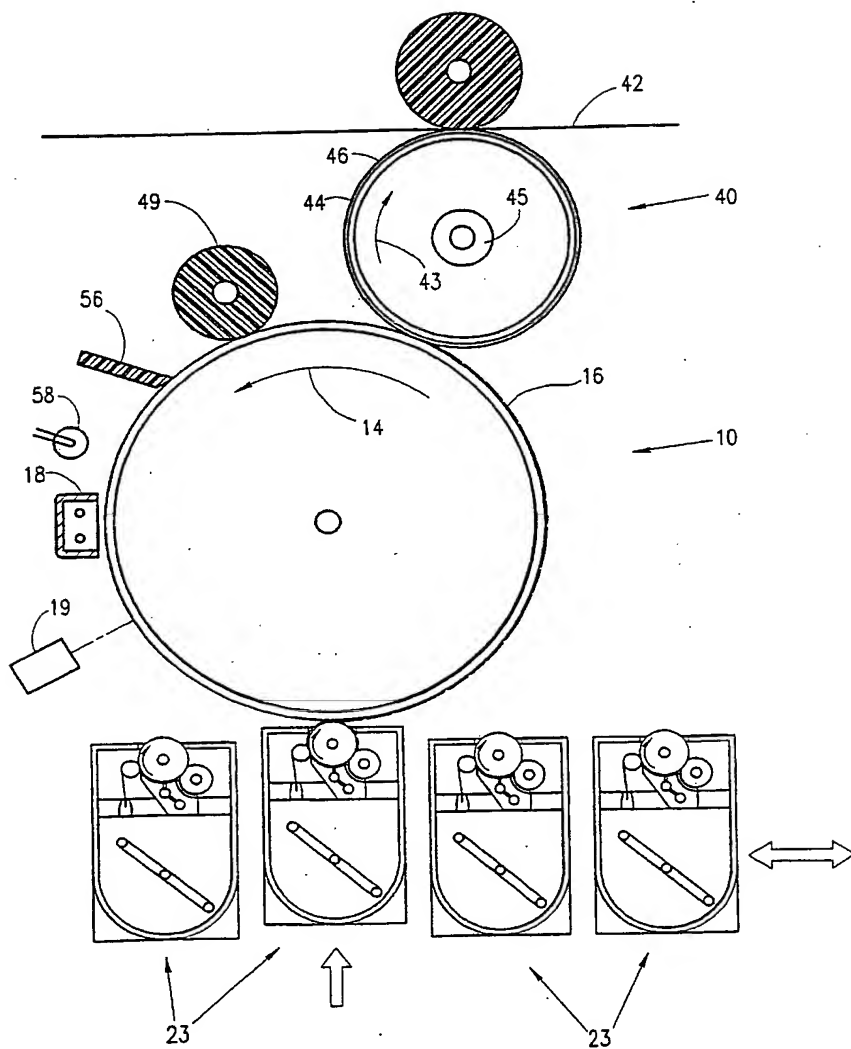


FIG. 2B

4/9

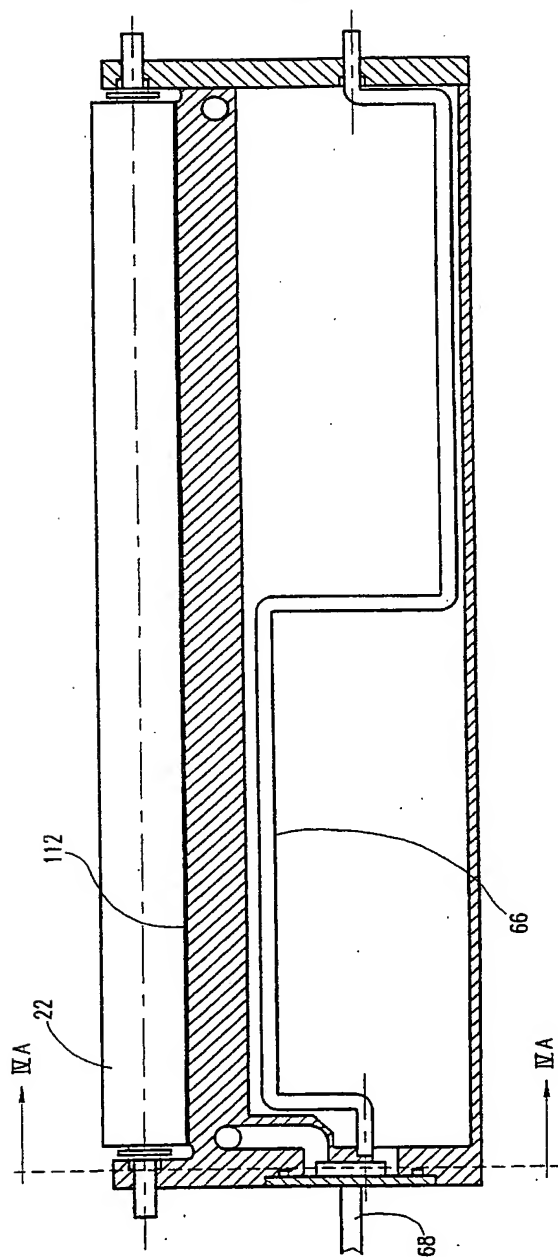


FIG. 3A

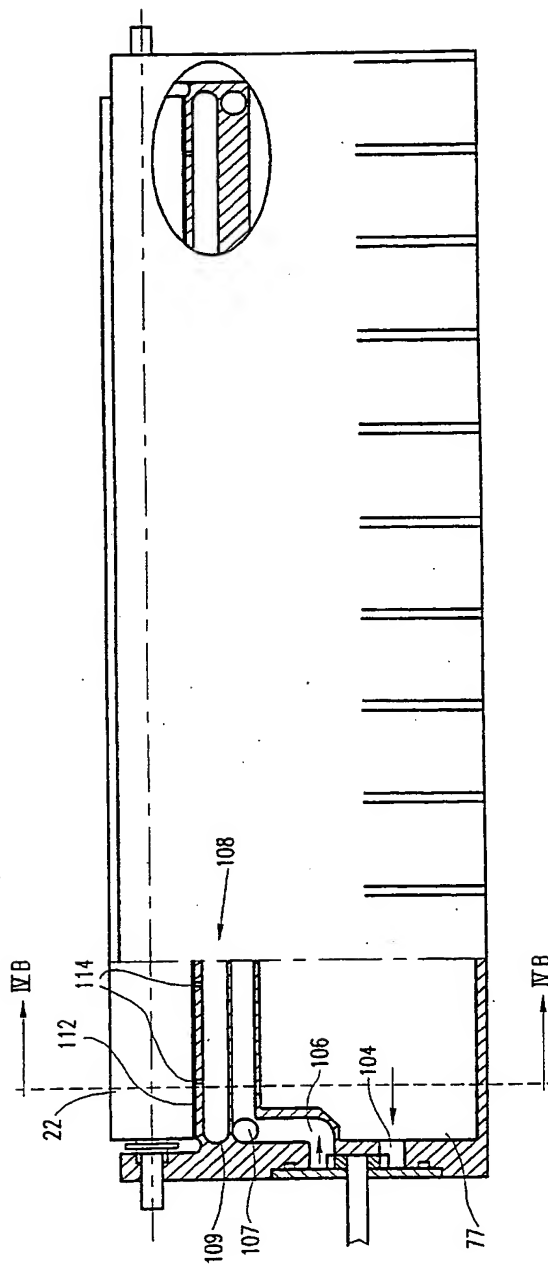


FIG. 3B

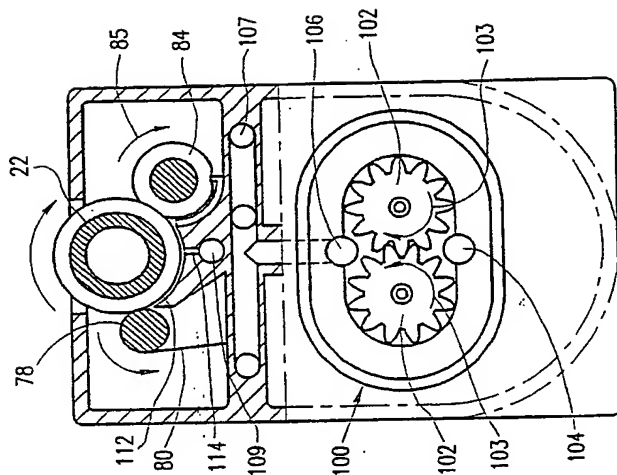


FIG. 4B

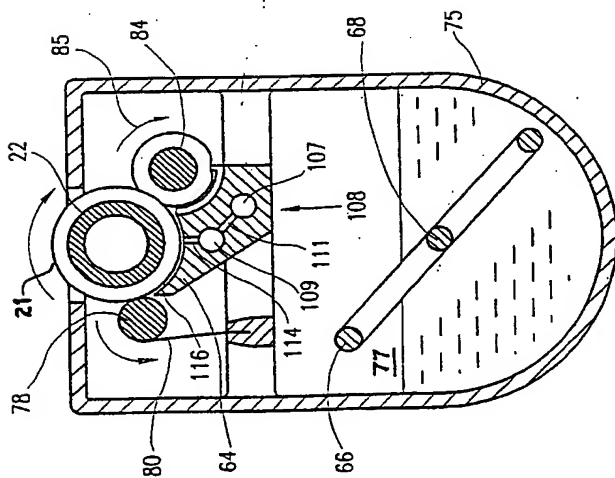


FIG. 4A

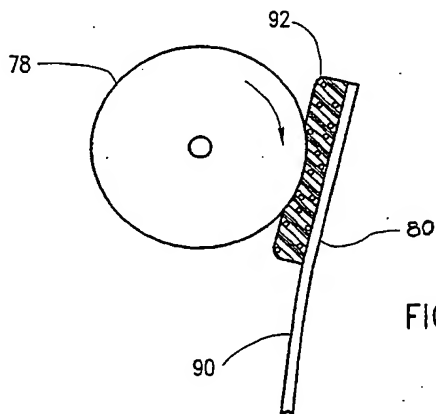
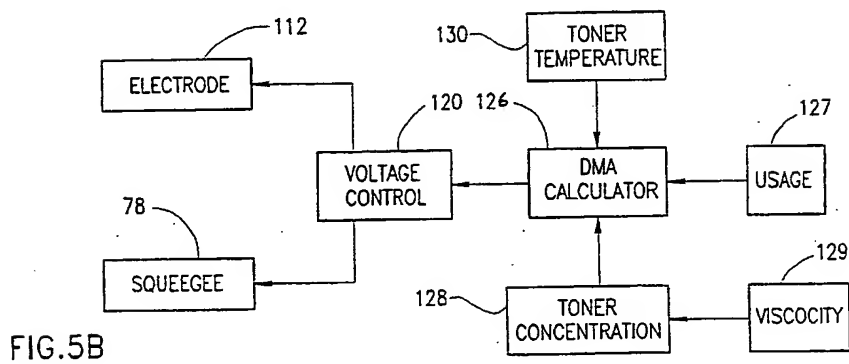
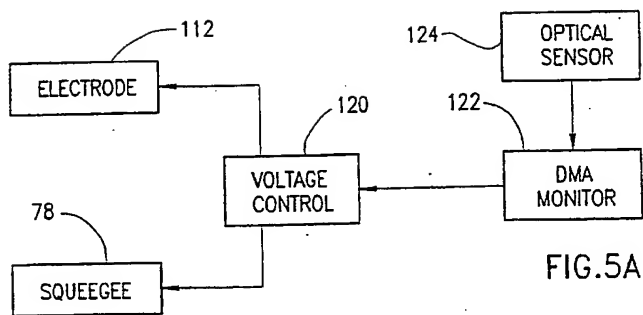


FIG.8

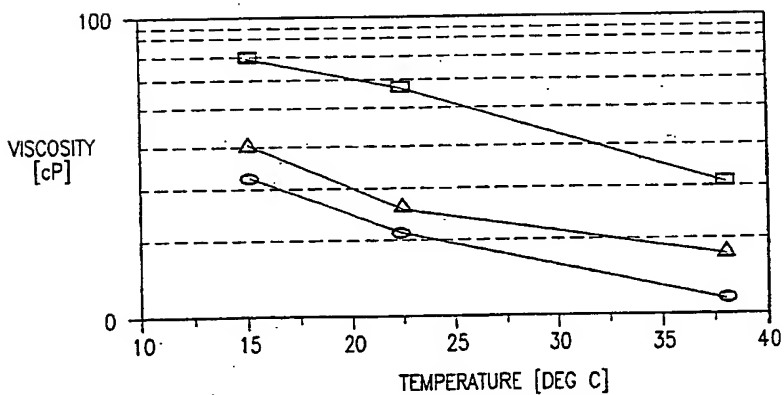
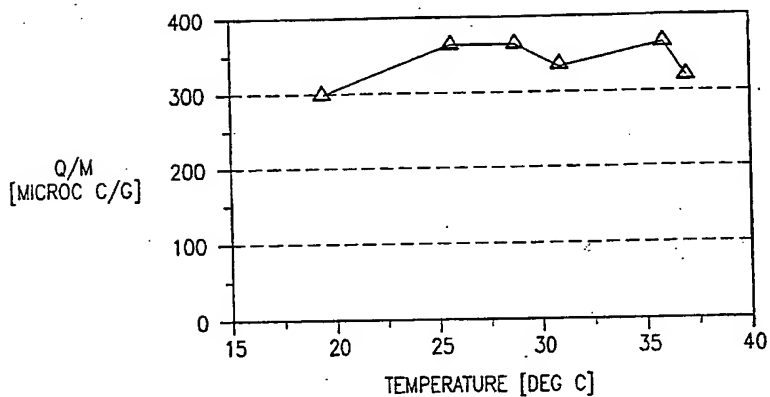


FIG.7

□ MARCOL-82 △ 2% NVS ○ 8% NVS

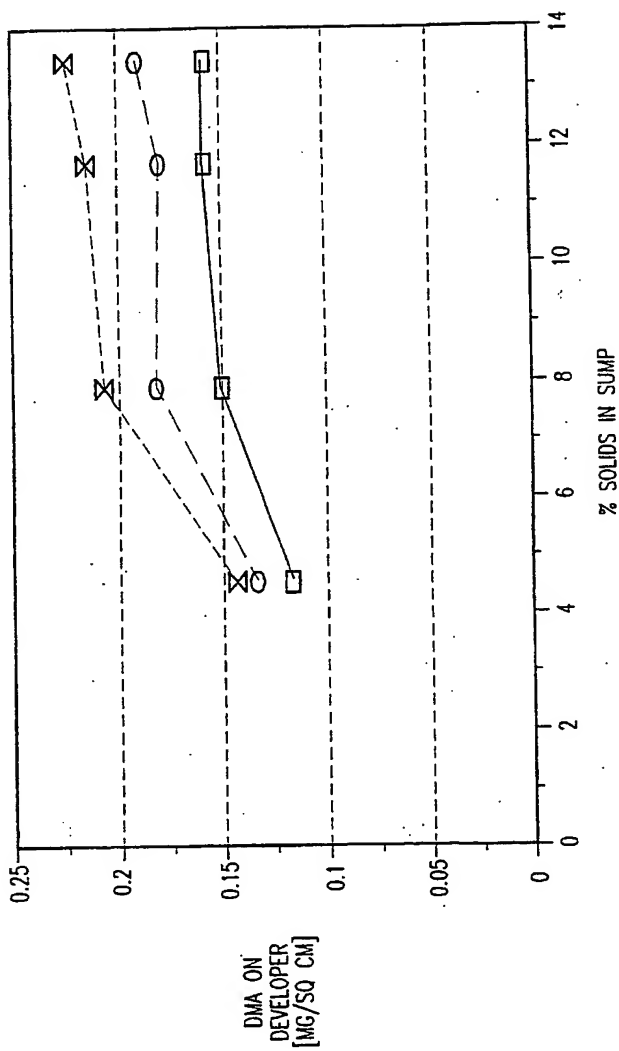


FIG.9

□ SQ VEC=345 V ○ SQ VEC=410 V ✕ SQ VEC=485 V

INTERNATIONAL SEARCH REPORT

Intern. Appl. No.
PCT/NL 94/00027A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03G15/10 G03G15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	---	3-6,8-11
Y	PATENT ABSTRACTS OF JAPAN vol. 011, no. 002 (P-532) 6 January 1987 & JP,A,61 179 480 (MATSUSHITA GRAPHIC COMMUN SYST INC) 12 August 1986 see abstract ---	1,2,7, 12-14,16
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search

23 November 1994

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

PCT/NL 94/00027

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

International Application No
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